



US009056014B2

(12) **United States Patent**
McCormick et al.

(10) **Patent No.:** **US 9,056,014 B2**
(45) **Date of Patent:** **Jun. 16, 2015**

(54) **DEVICE AND METHOD FOR FIXATION FOR BONE OR SOFT TISSUE DEFORMITY OF DIGITS**

(2013.01); *A61F 5/05875* (2013.01); *A61F 5/10* (2013.01); *A61B 17/7291* (2013.01); *A61B 17/86* (2013.01)

(71) Applicants: **Daniel F. McCormick**, Germantown, TN (US); **Vinay Patel**, Memphis, TN (US); **Scott A. Armacost**, Germantown, TN (US); **Timothy M. O'Kane**, Munford, TN (US); **Wesley Reed**, Libertyville, IL (US)

(58) **Field of Classification Search**
CPC *A61F 2/4241*; *A61F 2/4225*; *A61F 2/28*; *A61F 2/442*
USPC 623/16.11–17.16, 21.12–22.11
See application file for complete search history.

(72) Inventors: **Daniel F. McCormick**, Germantown, TN (US); **Vinay Patel**, Memphis, TN (US); **Scott A. Armacost**, Germantown, TN (US); **Timothy M. O'Kane**, Munford, TN (US); **Wesley Reed**, Libertyville, IL (US)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,783,758	A	3/1957	Trott
3,872,861	A	3/1975	Tamny et al.
4,644,941	A	2/1987	Ogle, II
5,649,541	A	7/1997	Stuckey
5,947,915	A	9/1999	Thibodo, Jr.

(Continued)

(73) Assignee: **Wright Medical Technology, Inc.**,
Arlington, TN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 125 days.

FOREIGN PATENT DOCUMENTS

JP S61-011039 A 1/1986

OTHER PUBLICATIONS

European Search Report for Application No. EP 13198279.5 dated May 2, 2014.

Primary Examiner — Jason-Dennis Stewart

(74) *Attorney, Agent, or Firm* — Duane Morris LLP

(21) Appl. No.: **13/828,593**

(22) Filed: **Mar. 14, 2013**

(65) **Prior Publication Data**

US 2014/0188237 A1 Jul. 3, 2014

Related U.S. Application Data

(60) Provisional application No. 61/746,426, filed on Dec. 27, 2012.

(51) **Int. Cl.**

<i>A61F 2/42</i>	(2006.01)
<i>A61F 2/28</i>	(2006.01)
<i>A61F 5/01</i>	(2006.01)
<i>A61F 5/10</i>	(2006.01)
<i>A61B 17/72</i>	(2006.01)
<i>A61F 5/058</i>	(2006.01)
<i>A61B 17/86</i>	(2006.01)

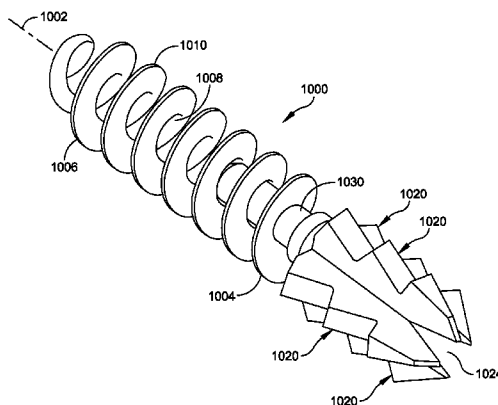
(52) **U.S. Cl.**

CPC *A61F 2/4225* (2013.01); *A61F 5/019*

(57) **ABSTRACT**

A fixation device comprises a first clamping member having an adjustable clamping collar and a first curved support portion attached to the adjustable clamping collar. The first clamping member is adapted to receive a digit. The first curved support portion is adapted to support an inferior surface of a proximal phalanx of the digit. A distal member is adjustably attachable to the first clamping member. The distal member has a second curved support surface adapted to support an inferior surface of a distal phalanx of the digit and a curved distal end adapted to apply a compressive force in a proximal direction to a distal end of the distal phalanx.

22 Claims, 23 Drawing Sheets



(56)

References Cited

U.S. PATENT DOCUMENTS

6,575,925 B1 6/2003 Noble

2008/0255487 A1 10/2008 Bolla
2011/0125265 A1 * 5/2011 Bagga et al. 623/16.11
2011/0301652 A1 * 12/2011 Reed et al. 606/319

* cited by examiner

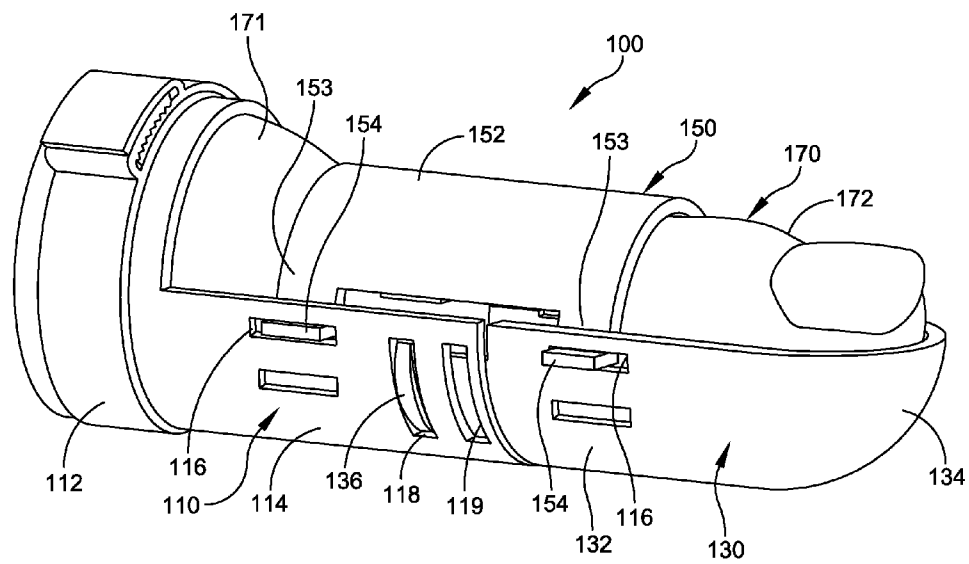


FIG. 1

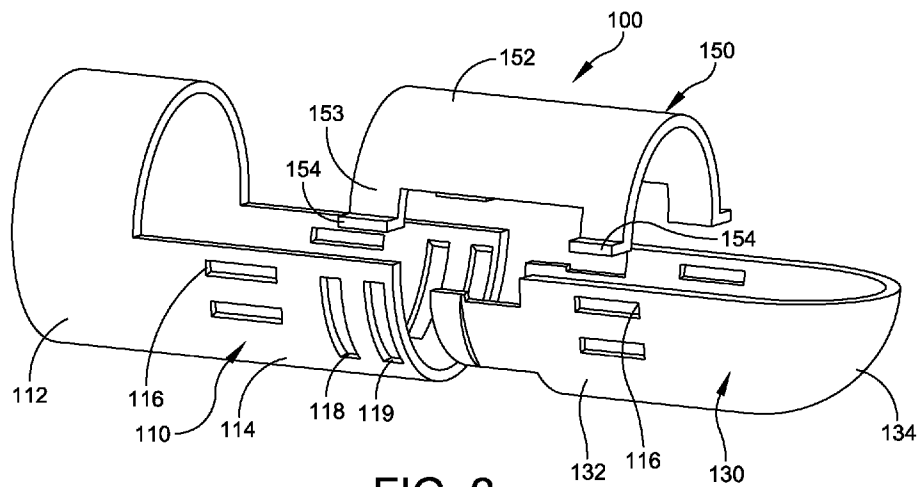


FIG. 2

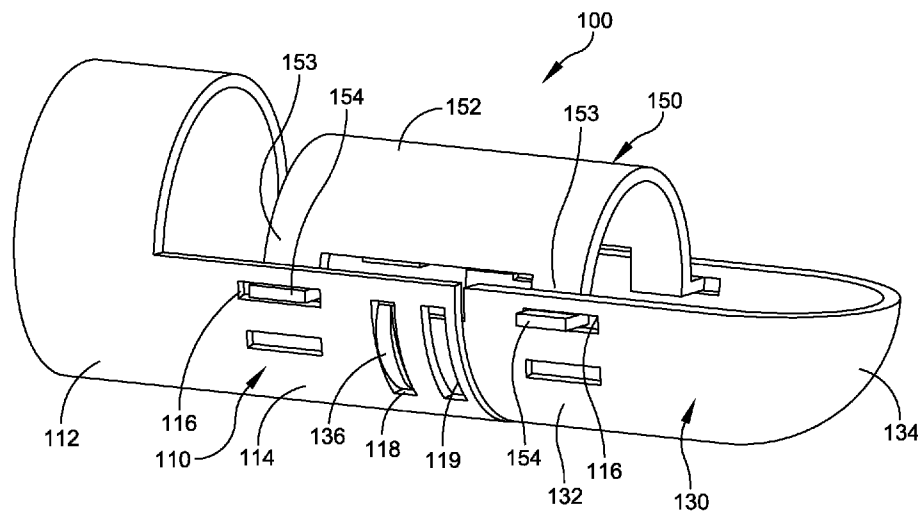


FIG. 3

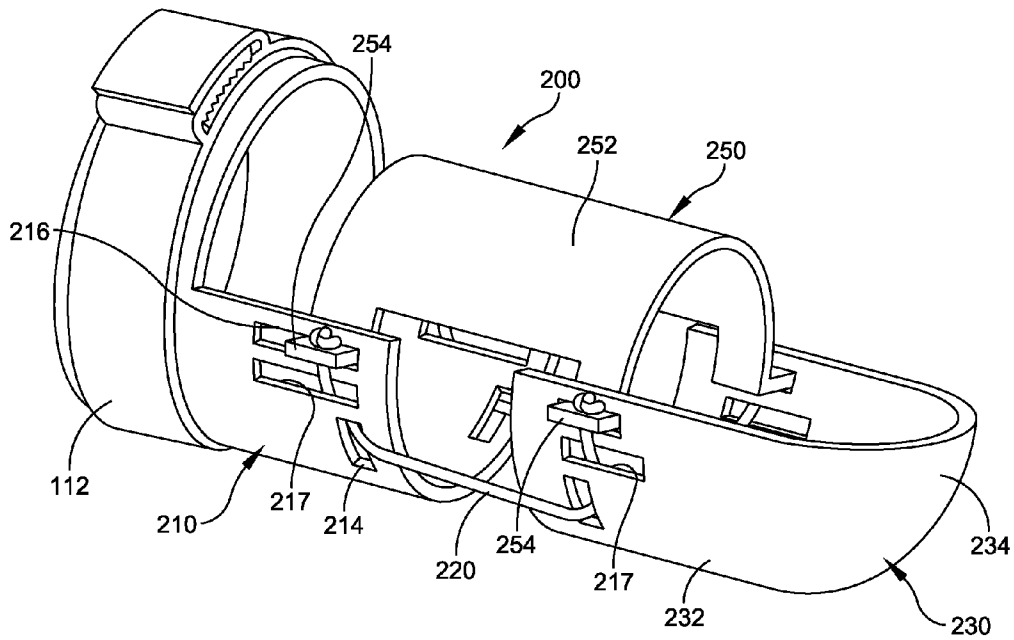


FIG. 4

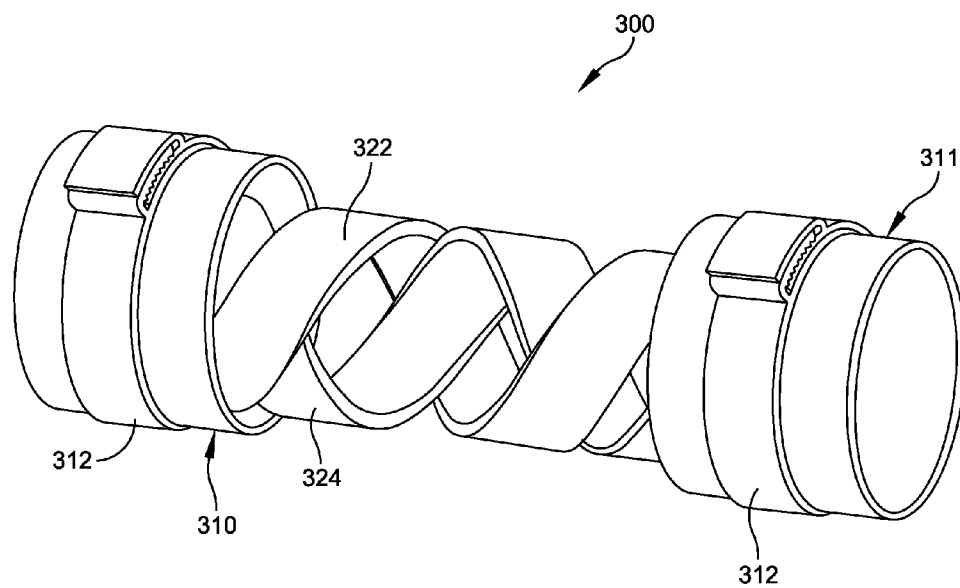


FIG. 5

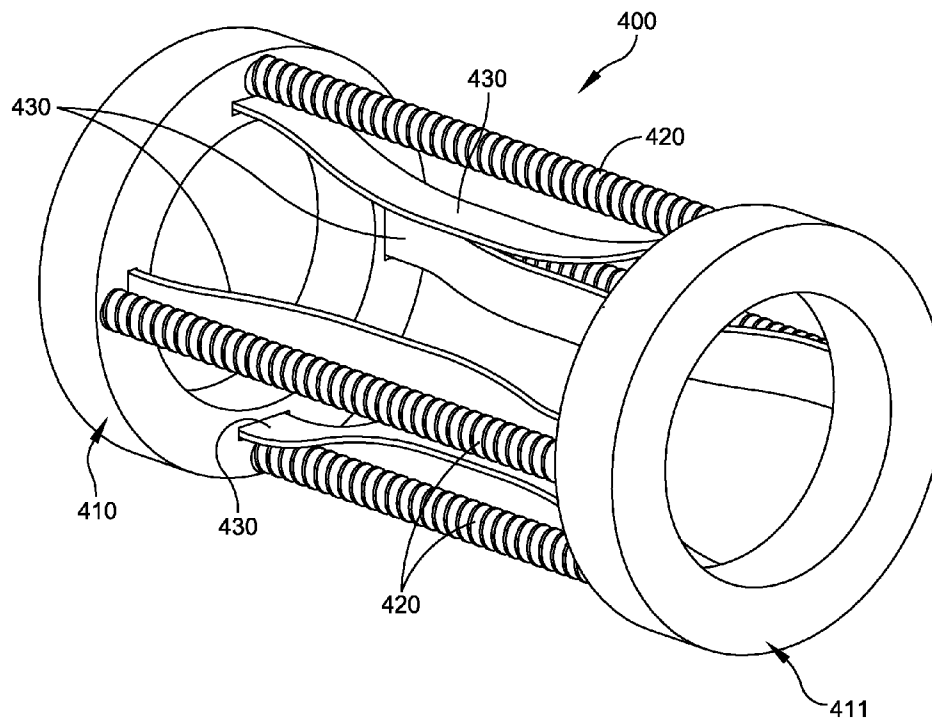


FIG. 6

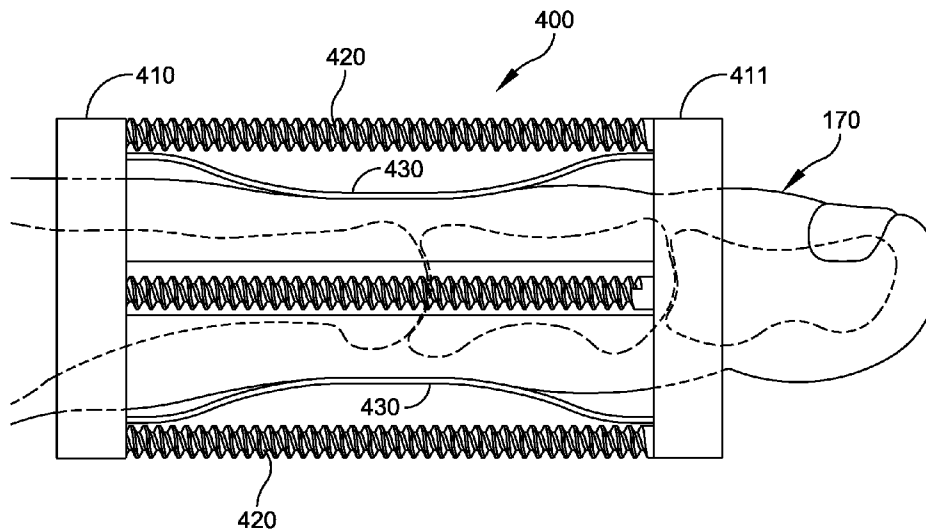


FIG. 7

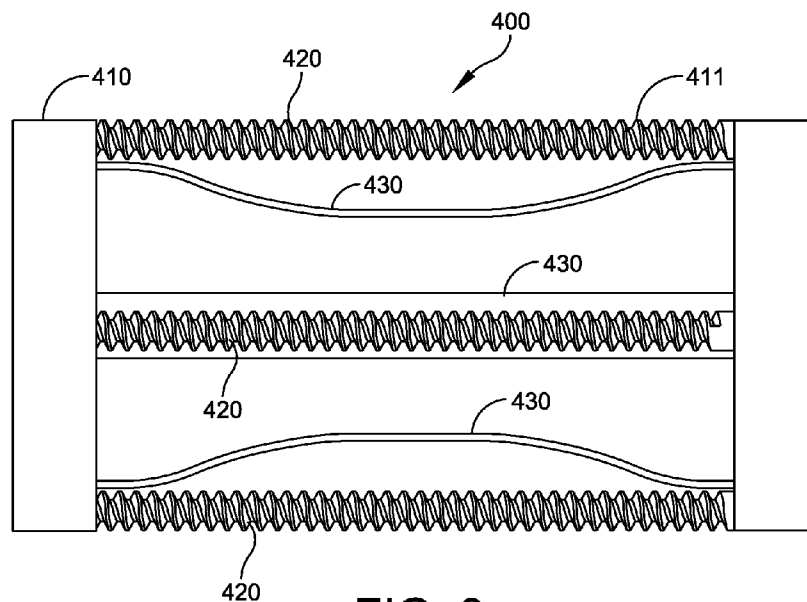


FIG. 8

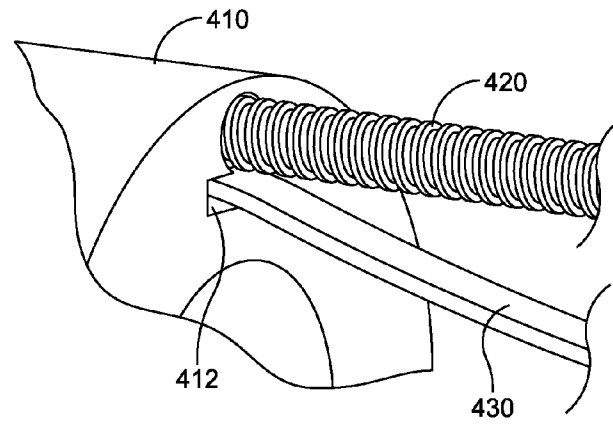


FIG. 9

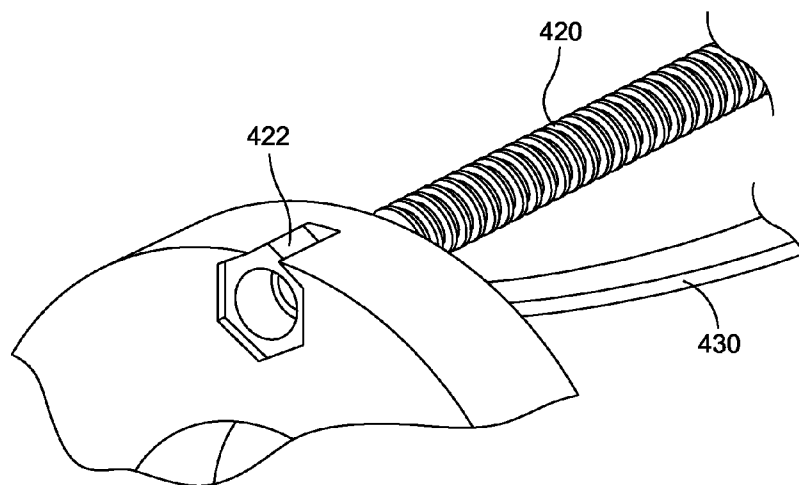


FIG. 10

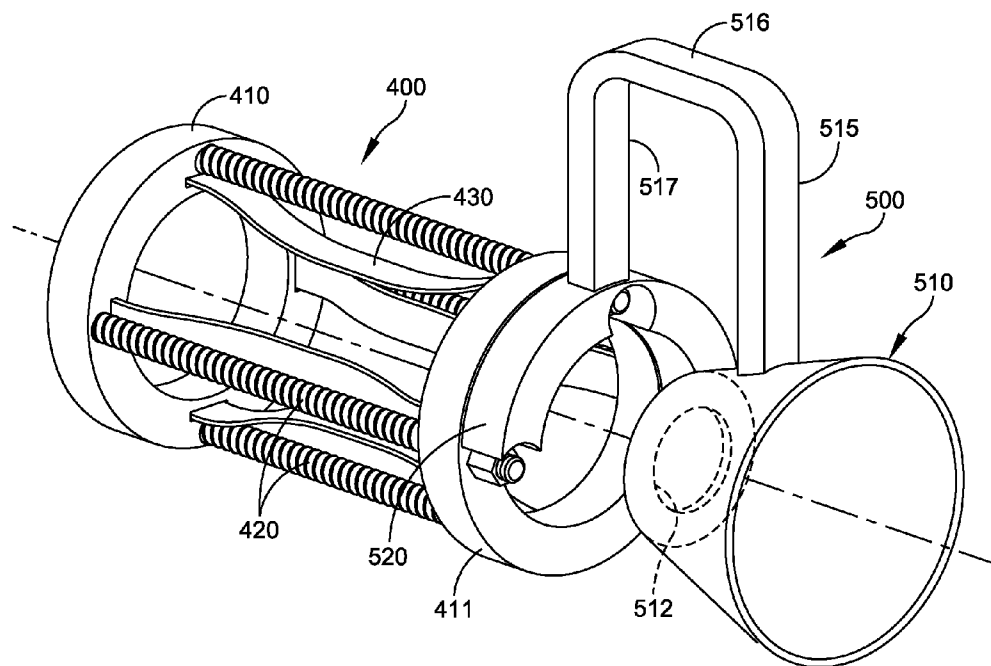


FIG. 11

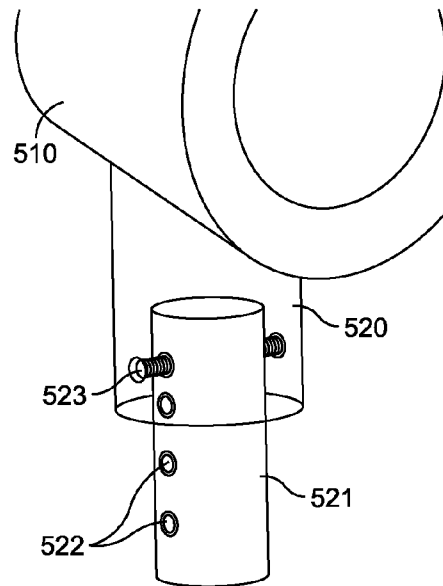


FIG. 11A

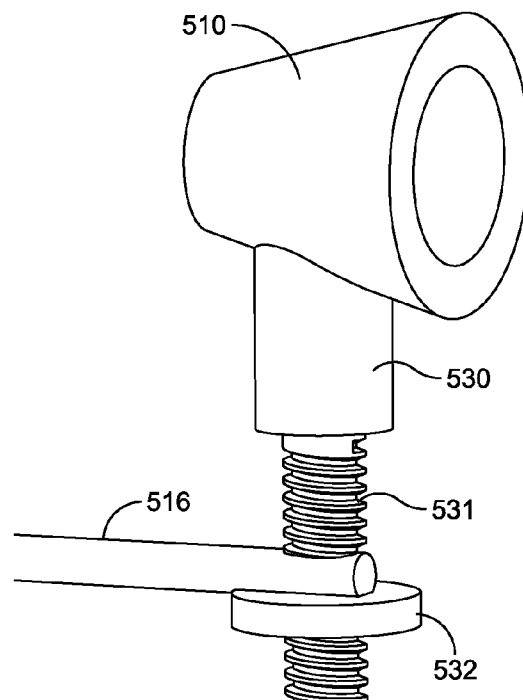


FIG. 11B

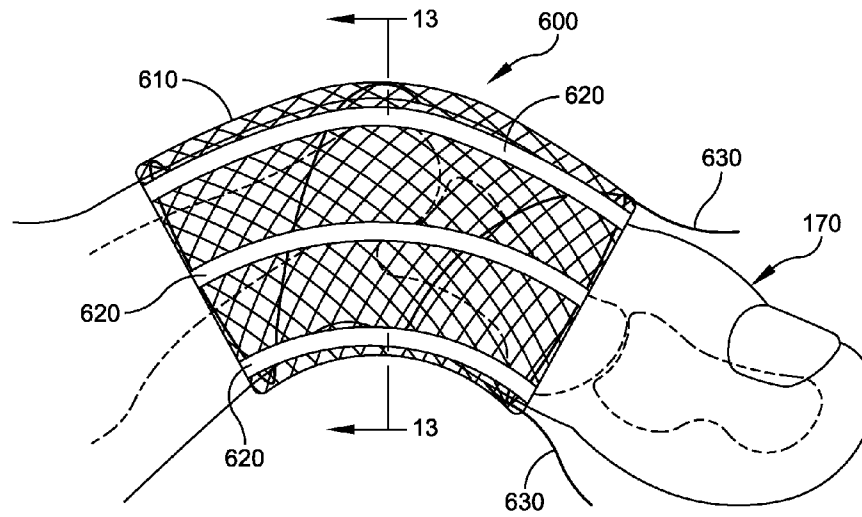


FIG. 12

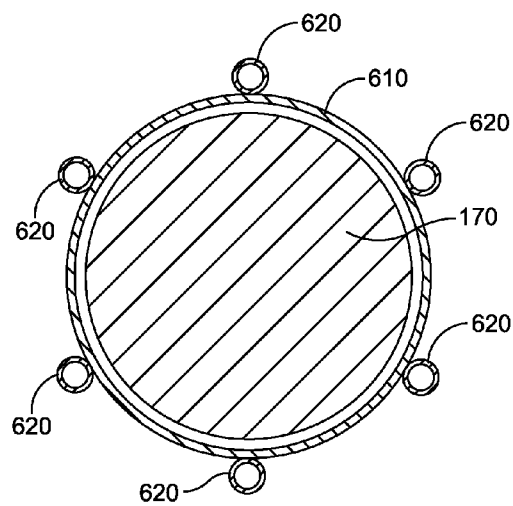


FIG. 13

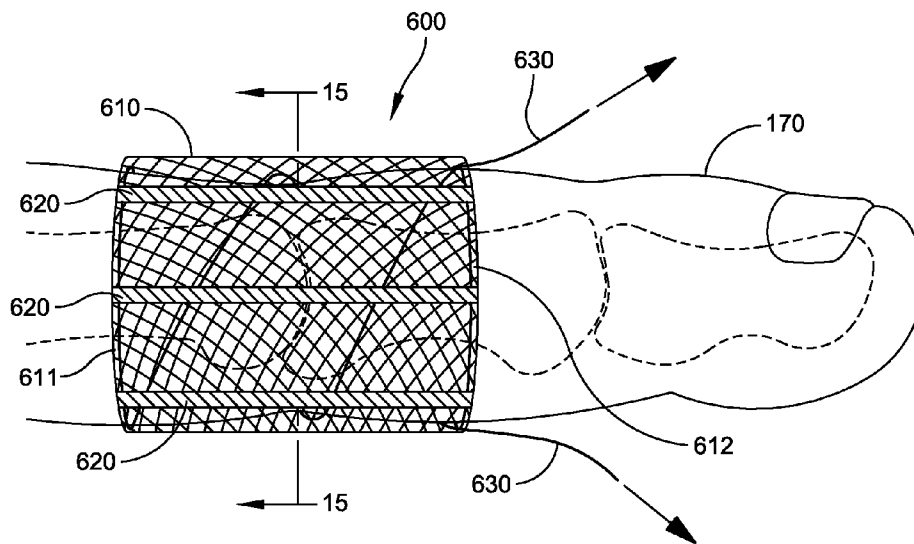


FIG. 14

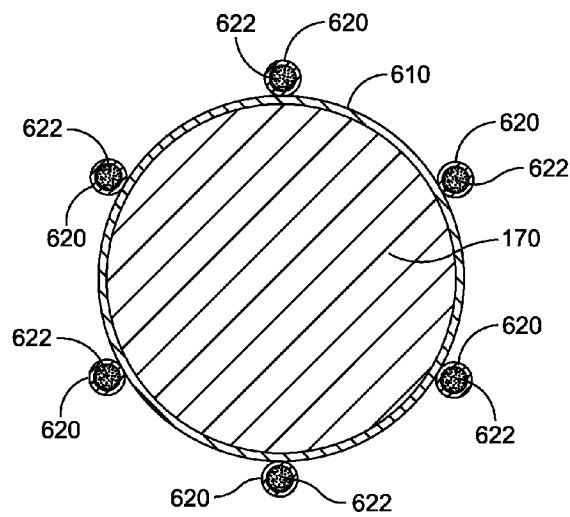


FIG. 15

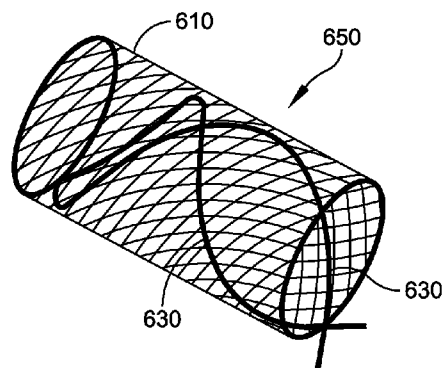


FIG. 15A

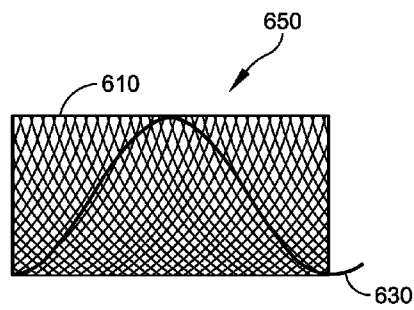


FIG. 15B

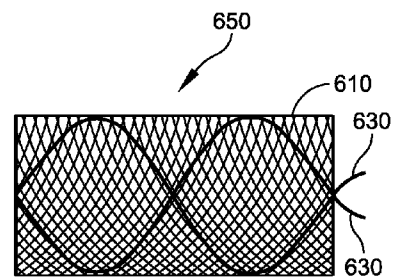


FIG. 15C

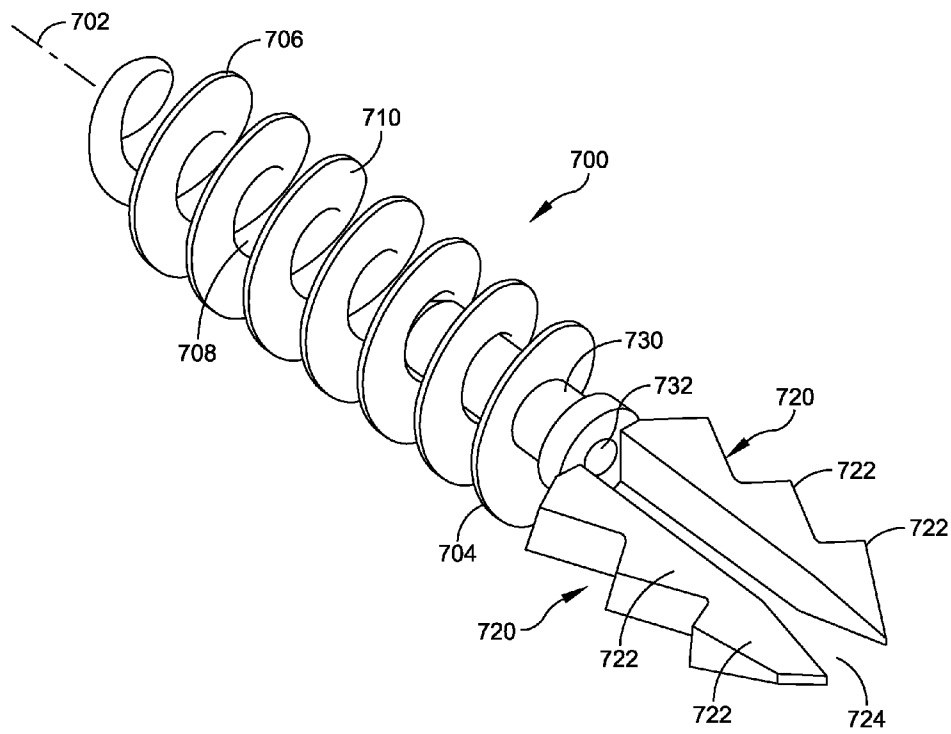


FIG. 16

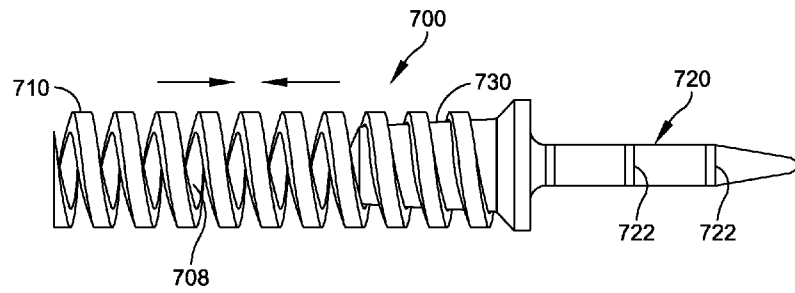


FIG. 17

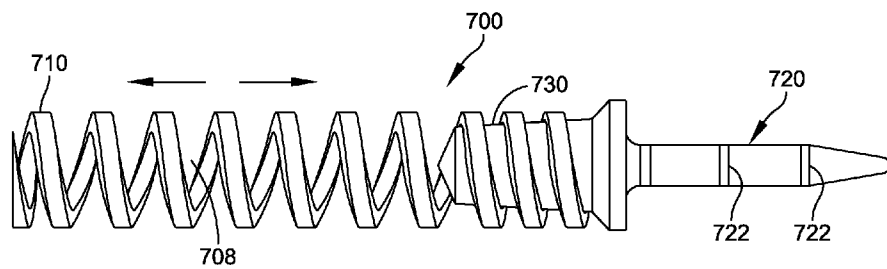


FIG. 18

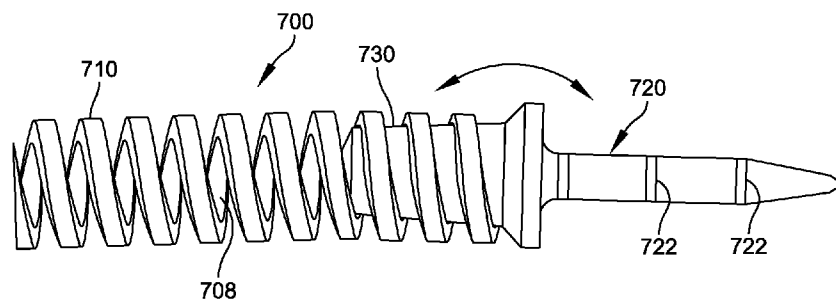


FIG. 19

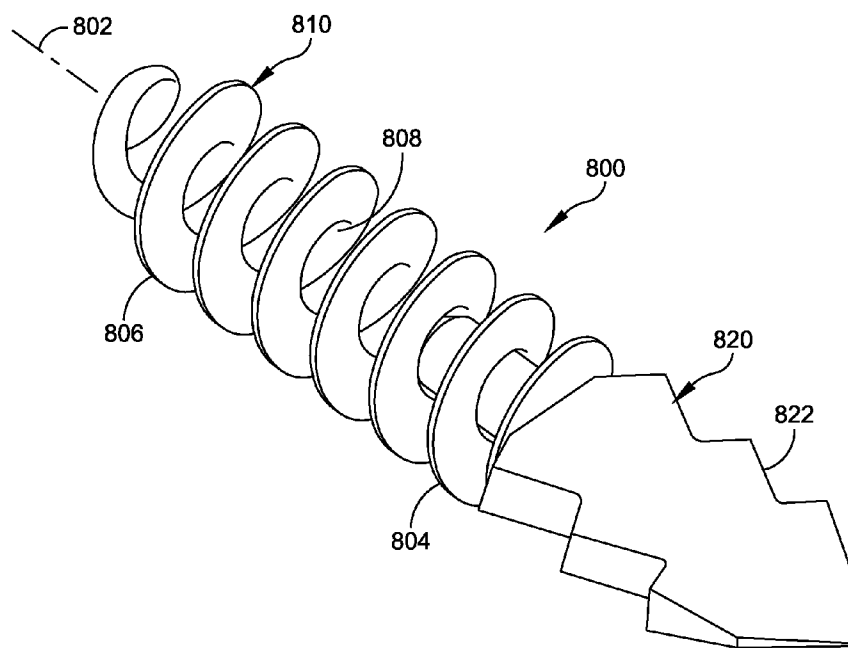


FIG. 20

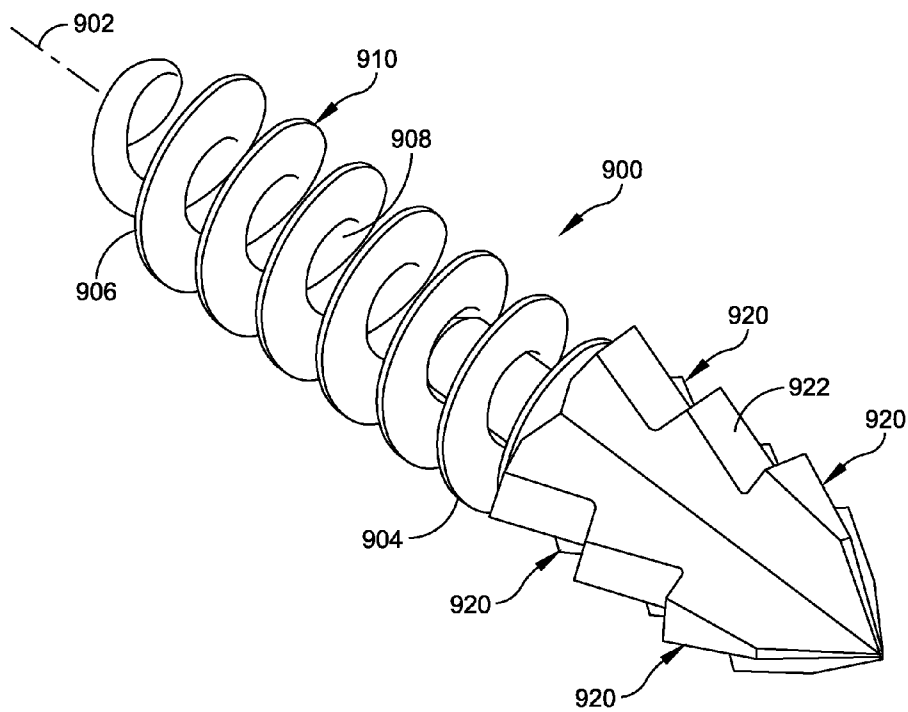


FIG. 21

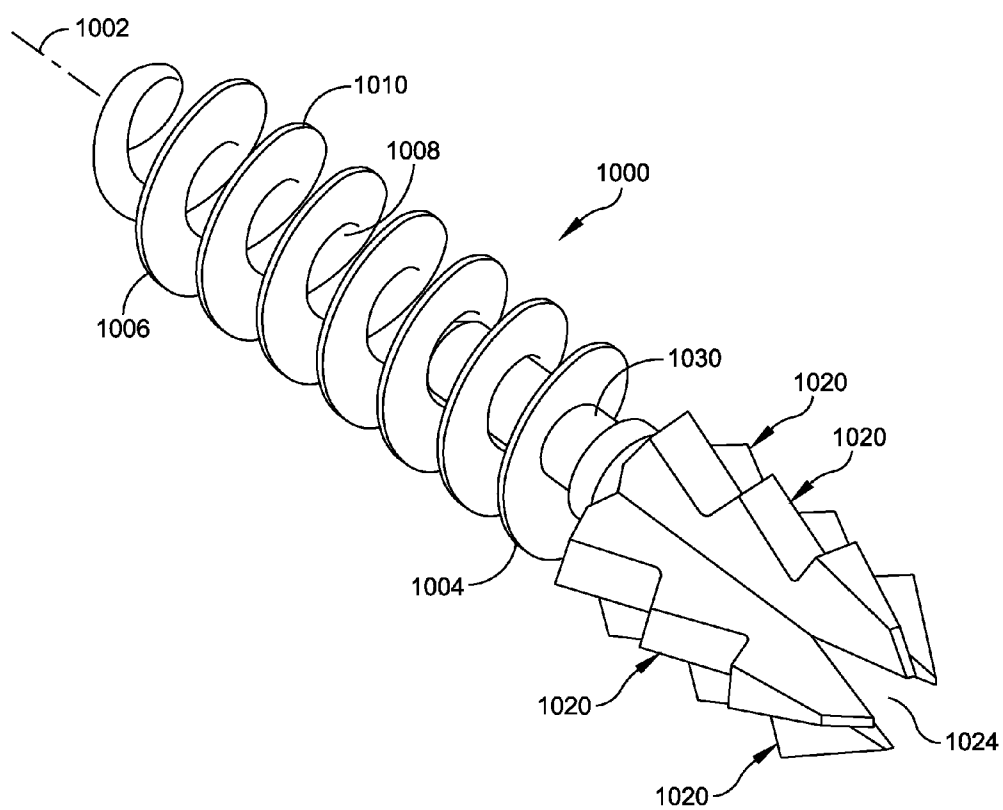
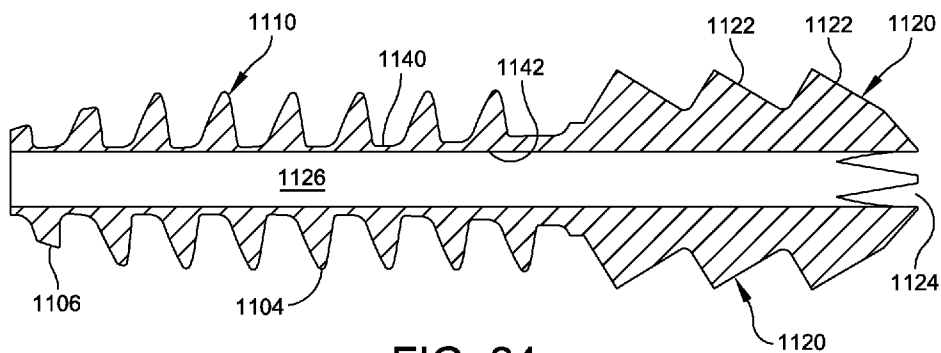
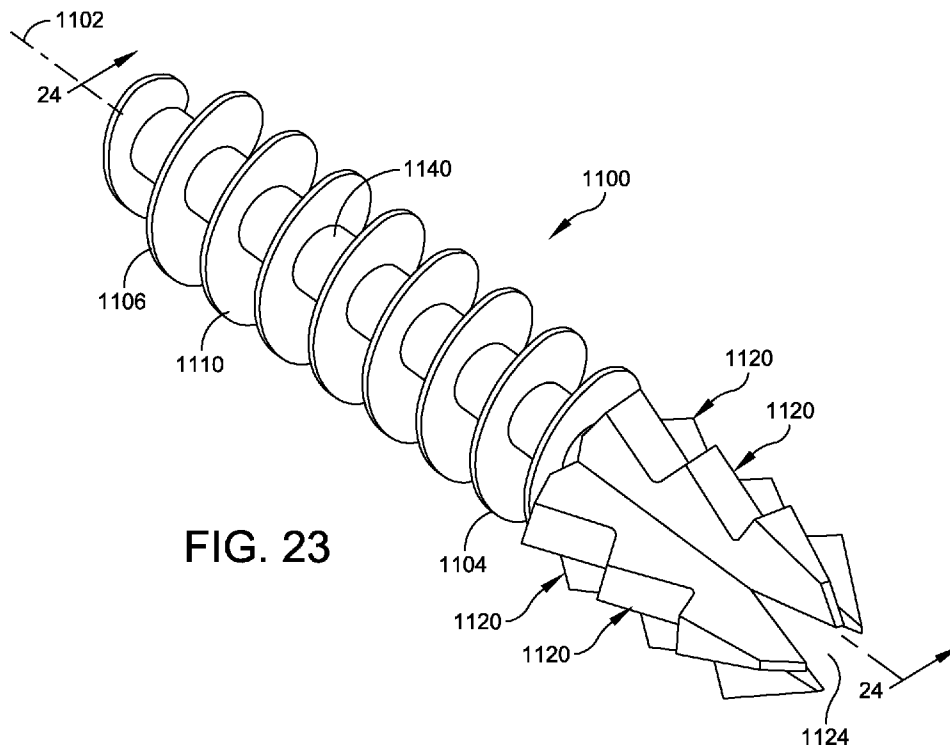


FIG. 22



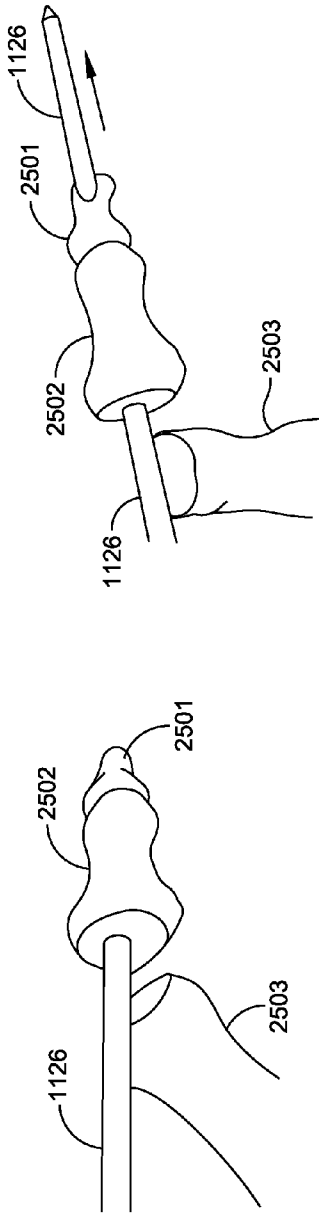


FIG. 26

FIG. 25

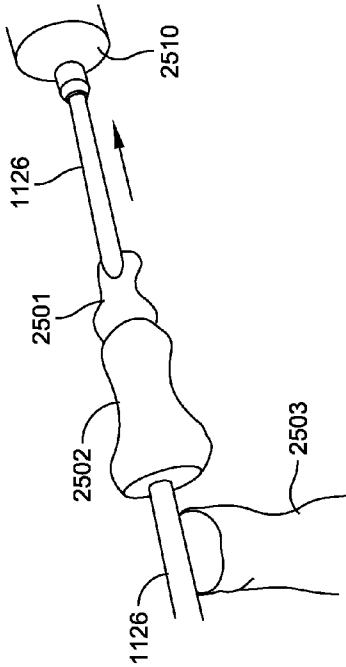


FIG. 27

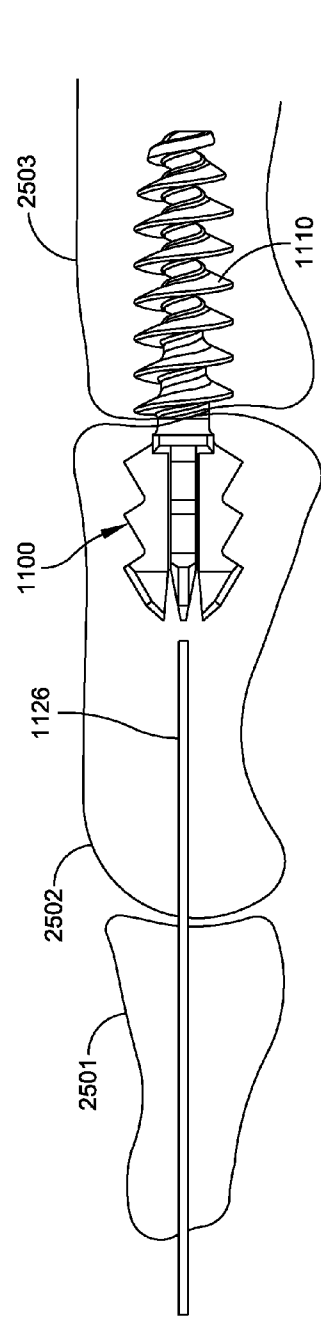


FIG. 28

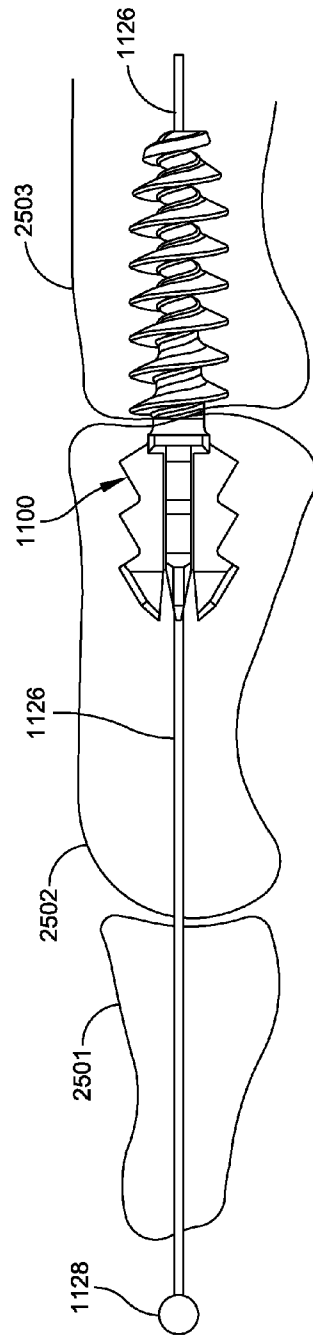


FIG. 29

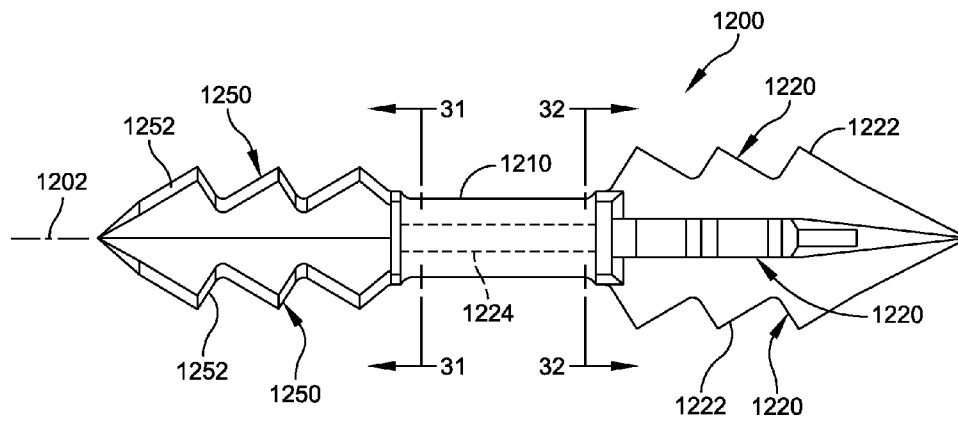


FIG. 30

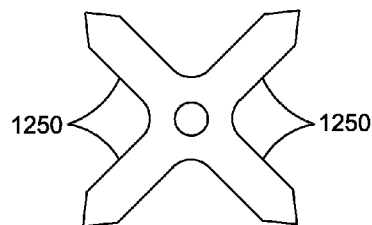


FIG. 31

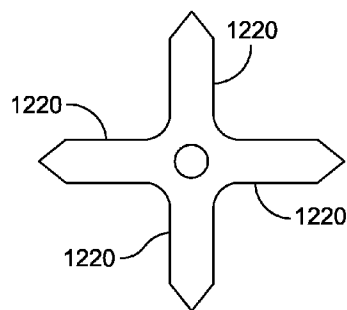


FIG. 32

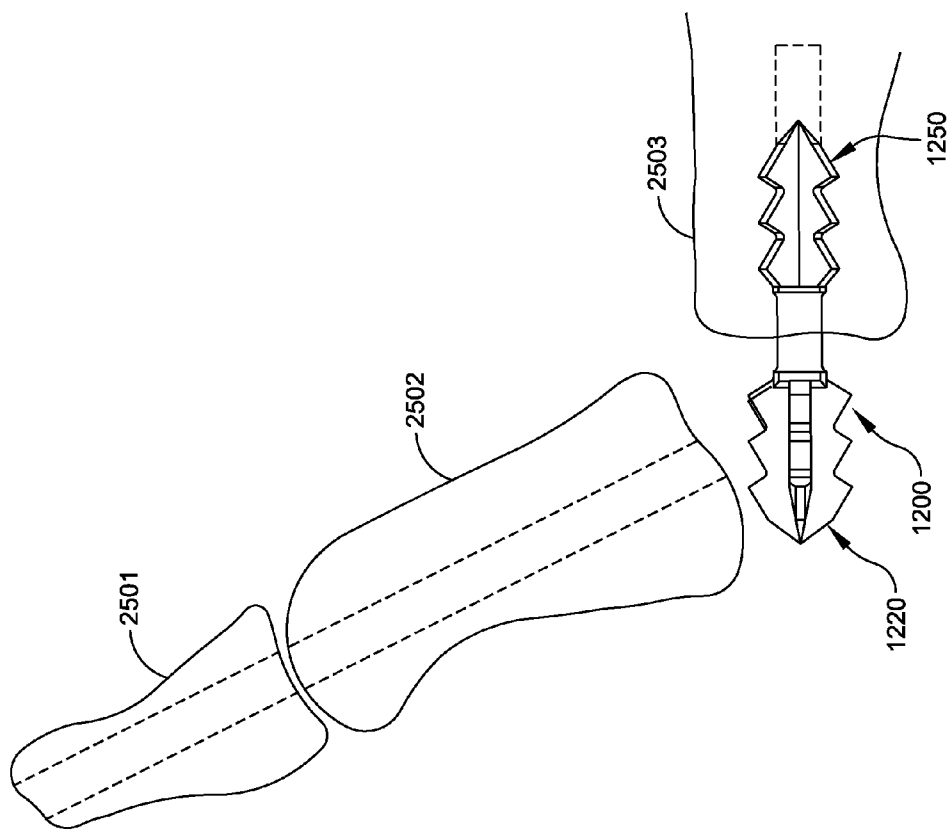


FIG. 33

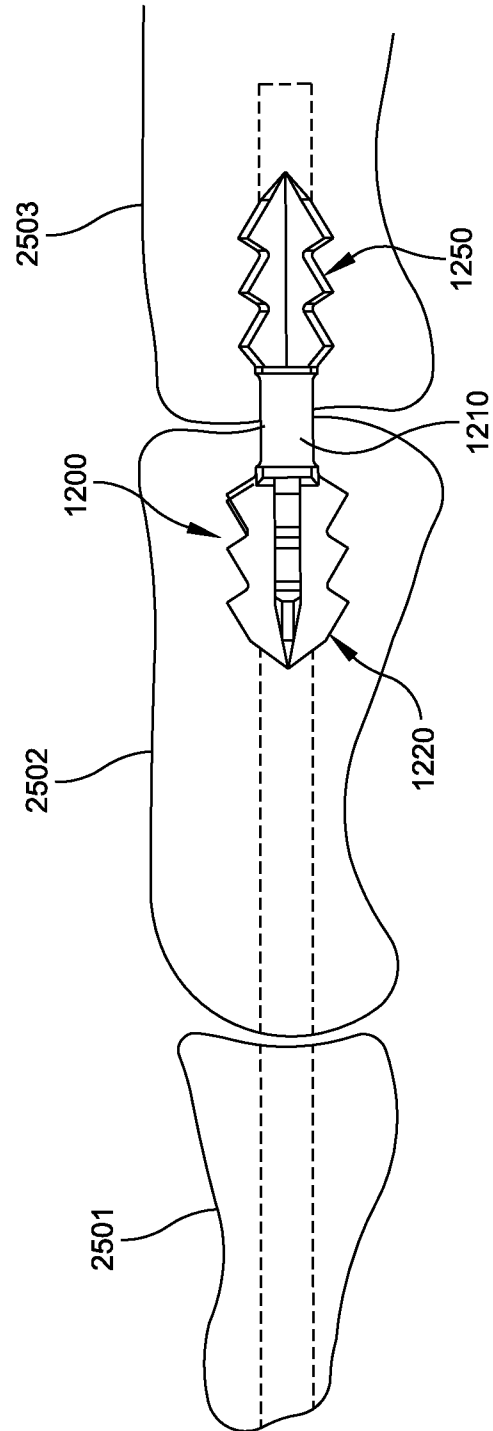


FIG. 34

1

DEVICE AND METHOD FOR FIXATION FOR BONE OR SOFT TISSUE DEFORMITY OF DIGITS

This application claims the benefit of U.S. provisional application No. 61/746,426, filed on Dec. 27, 2012, the entirety of which is incorporated herein by reference.

FIELD

This disclosure relates to medical devices.

BACKGROUND

Fingers and toes may become deformed. A hammertoe is a deformity of the tissues surrounding the bony structures of the lesser toes. The patient's toes elevate and cause discomfort while wearing shoes. For example, poorly fitting shoes can cause a hammertoe deformity of the proximal interphalangeal (PIP) joint of any of the lesser toes causing it to be permanently bent. Osteoarthritis, rheumatoid arthritis, stroke, Charcot-Marie-Tooth disease or diabetes may cause muscle, nerve, or joint damage which may also deform one or more joints.

Depending on the degree of deformity and the patient's history, a doctor may determine that fixation of the affected digit is appropriate to correct the deformity. For example, Wright Medical Technologies of Arlington, Tenn. provides the "PRO-TOE"® line of bone implants for correcting a hammertoe deformity. A threaded member has a longitudinal axis and threads extending from the proximal end to the distal end. A toothed blade is integrally attached to the distal end of the threaded member. The blade extends in a radial direction away from the longitudinal axis. The blade has an outer edge with a plurality of teeth on it.

Improved fixation devices and methods are desired for correcting joint deformities, such as hammertoe and the like.

SUMMARY

In some embodiments, a fixation device comprises a first clamping member having an adjustable clamping collar and a first curved support portion attached to the adjustable clamping collar. The first clamping member is adapted to receive a digit therethrough. The first curved support portion is adapted to support an inferior surface of a proximal phalanx of the digit. A distal member is adjustably attachable to the first clamping member. The distal member has a second curved support surface adapted to support an inferior surface of a distal phalanx of the digit and a curved distal end adapted to apply a compressive force in a proximal direction to a distal end of the distal phalanx.

In some embodiments, a fixation device comprises a proximal clamping member and a distal clamping member. Each of the proximal and distal clamping members has an adjustable clamping collar adapted to receive a digit therethrough. First and second coaxial helical members are provided, opposing each other. Each of the helical members has a respective proximal end fixedly attached to the proximal clamping member and a respective distal end fixedly attached to the distal clamping member.

In some embodiments, a fixation device comprises a proximal clamping member and a distal clamping member. Each of the proximal and distal clamping members has an adjustable clamping collar adapted to receive a digit therethrough. A plurality of longitudinal spacers each have a proximal end attached to the proximal clamping member and a distal end

2

attached to the distal clamping member. A plurality of spring members have a proximal end attached to the proximal clamping member and a distal end attached to the distal clamping member. Each spring member is located adjacent to and radially inward from a respective longitudinal spacer. Each longitudinal spacer constrains its respective spring member to bow radially inwards.

In some embodiments, a fixation device comprises a tube comprising a contractible tubular woven mesh configured to contract radially under longitudinal tension. At least one helical yarn or fiber is fastened at or near a first end of the tube and woven helically through the mesh and extends from a second end of the tube opposite the first end of the tube, such that the yarn is capable of applying radial compression to the tube when placed under tension.

In some embodiments, a fixation device comprises a tube comprising a contractible tubular woven mesh configured to contract radially under longitudinal tension. A plurality of sleeves are arranged around an outer surface of the tube, the sleeves smaller in diameter than the tube. At least one rib is removably insertable in at least a respective one of the plurality of sleeves. The at least one rib is formed of a material that is more rigid than a material of the tubular woven mesh.

In some embodiments, a bone implant comprises a helical threaded member having first and second ends and a longitudinal central opening extending from the first end to the second end. The longitudinal central opening has a longitudinal axis. At least one blade is integrally attached to the first end of the helical threaded member. The blade extends in a radial direction away from the longitudinal axis. The blade has an outer edge with a plurality of teeth thereon.

In some embodiments, a bone implant comprises a central shaft having first and second ends and a longitudinal axis. A first set of blades are integrally attached to the first end of the central shaft. The first set of blades extend in a radial direction away from the central shaft. Each of the first set of blades having an outer edge with a plurality of teeth thereon. A second set of blades are integrally attached to the second end of the central shaft. The second set of blades extend in the radial direction away from the central shaft. Each of the second set of blades has an outer edge with a plurality of teeth thereon. The second set of blades are rotationally offset from the first set of blades.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side perspective view of an external fixation/correction device formed in accordance with an embodiment of the invention for use in correcting deformities in a toe or finger;

FIG. 2 is a perspective exploded view of the external fixation/correction device shown in FIG. 1;

FIG. 3 is a perspective view of the external fixation/correction device shown in FIGS. 1 and 2 with a superior member engage with remainder of the device;

FIG. 4 is a perspective view of an alternative embodiment of external fixation/correction device including a strap or band woven through slots in the clamping member;

FIG. 5 is a side perspective view of a second embodiment of external fixation/correction device for use in correcting deformities of a toe or finger;

FIG. 6 is a perspective view of a third embodiment of external fixation/correction device for use in correcting deformities of the toe or finger;

FIG. 7 is a side elevational view of the external fixation/correction device shown in FIG. 6, with a broken away, partially phantom finger positioned within the device;

3

FIG. 8 is a side elevational view of the external fixation/correction device shown in FIG. 7;

FIG. 9 is a broken away, enlarged view of a portion of the external fixation/correction device shown in FIGS. 6, 7 and 8;

FIG. 10 is a broken away, perspective view of the external fixation/correction device shown in FIGS. 7, 8 and 9;

FIG. 11 is a perspective view, partially in phantom, of a drill guide suitable for use with the fixation/correction devices shown in FIGS. 1-10;

FIG. 11A is a broken away, detailed view of an adjustment mechanism for the drill guide shown in FIG. 11;

FIG. 11B is a further broken away detail of another adjustment mechanism for the drill guide shown in FIG. 11;

FIG. 12 is a side elevational view, partially in phantom, of yet a further embodiment of external fixation/correction device for correction of deformities in a toe or finger;

FIG. 13 is a cross sectional view taken along line 13-13 in FIG. 12;

FIG. 14 is a side perspective view, partially in phantom, of the fixation/correction devices shown in FIGS. 12-13;

FIG. 15 is a cross sectional view, taken along the lines 15-15, in FIG. 14;

FIG. 15A is a perspective view of an alternative embodiment of external fixation/correction device including helical yarn or fiber that are woven into a tubular mesh;

FIG. 15B is a side elevational view of the external fixation/correction device shown in FIG. 15A;

FIG. 15C is a side elevational view of the external fixation/correction device shown in FIGS. 15A and 15B;

FIG. 16 is a perspective view of a bone implant, formed in accordance with the invention used for correcting deformities of a toe or a finger;

FIG. 17 is a side elevational view of the bone implant shown in FIG. 16;

FIG. 18 is a further side perspective view of the bone implant shown in FIGS. 16 and 17;

FIG. 19 is a side elevational view of the bone implant shown in FIG. 18, showing the compliance of a helical threaded member;

FIG. 20 is a perspective view of an alternative embodiment of bone implant formed in accordance with the invention;

FIG. 21 is a perspective view of yet another embodiment of bone implant, including a multiple barbed end;

FIG. 22 is a perspective view of a further embodiment of bone implant formed in accordance with the invention, including an alternative multiple barb portion;

FIG. 23 is a perspective view of the bone implant shown in FIG. 22;

FIG. 24 is a cross sectional view of the bone implant shown in FIG. 23 is taken along lines 24-24;

FIG. 25 is a perspective view of a proximal bone that has been pre-drilled to receive a K wire in accordance with one method of the invention;

FIG. 26 is a perspective view of a proximal bone shown in FIG. 25 illustrating a physician drilling distally through a middle phalanx;

FIG. 27 is a perspective view showing a K wire exposed with a drill attached to the distal end of the K wire;

FIG. 28 is a side elevational view, partially in perspective, of a proximal phalanx having a helical threaded portion of a bone implant fully seated;

FIG. 29 is a perspective view, similar to FIG. 28, showing K wire fully seated within the bone implant and proximal phalanx;

FIG. 30 is a side elevational view of a bone implant in accordance with a further embodiment of the invention;

4

FIG. 31 is an end view of the bone implant shown in FIG. 30;

FIG. 32 is a further end view of the bone implant shown in FIG. 30;

FIG. 33 is an exploded, partially perspective view of a set of phalanges having a bone implant lodged within a portion; and

FIG. 34 is a side elevational view, partially in phantom partially in perspective, showing the bone implant of FIG. 33 fully assembled within the proximal and distal phalanges.

DETAILED DESCRIPTION

This description of the exemplary embodiments is intended to be read in connection with the accompanying drawings, which are to be considered part of the entire written description. In the description, relative terms such as "lower," "upper," "horizontal," "vertical," "above," "below," "up," "down," "top" and "bottom" as well as derivative thereof (e.g., "horizontally," "downwardly," "upwardly," etc.) should be construed to refer to the orientation as then described or as shown in the drawing under discussion. These relative terms are for convenience of description and do not require that the apparatus be constructed or operated in a particular orientation. Terms concerning attachments, coupling and the like, such as "connected" and "interconnected," refer to a relationship wherein structures are secured or attached to one another either directly or indirectly through intervening structures, as well as both movable or rigid attachments or relationships, unless expressly described otherwise.

FIGS. 1 to 3 show an embodiment of an external fixation device 100. FIG. 2 is an exploded view. FIG. 3 shows the assembled device. Once assembled and applied to a digit (e.g., toe), the device 100 achieves axial compression, radial compression and superior/inferior stabilization. The device 100 can be used by itself for non-invasive treatment, or as a fixation and support device during recovery from a surgical procedure. FIG. 1 shows the assembled device in use for correcting a hammertoe deformity.

The device 100 has a proximal first clamping member 110 having an adjustable clamping collar 112 and a first curved support portion 114 attached to the adjustable clamping collar 112. The first clamping member 110 is adapted to receive a digit 170 (e.g., a toe or finger) therethrough. The first curved support portion 114 is adapted to support an inferior surface of a proximal phalanx 171 of the digit 170. The circular clamping collar 112 allows for radial compression on the proximal side of the joint-line. The collar 112 as shown has a ratchet mechanism with ramped teeth which permit tightening, but retain the clamp in position once tightened.

Although FIG. 1 shows ratchet type clamping collar 112, other clamping collars can be used. For example, some embodiments include a clamping mechanism of a type used in cable ties. Some embodiments include a hook and locking latch type clamping collar. Some embodiments include a worm drive clamping mechanism (similar to the drive of a hose clamp). Other embodiments include circular springs of various configurations, which the doctor can pinch to expand, and which are biased to contract and provide compression upon release. Other embodiments include hook and loop fasteners on ends of a band encircling the clamping collar 112. These are only examples of clamping mechanisms, and other embodiments include other types of clamping mechanisms.

A distal member 130 is adjustably attachable to the first clamping member 110. The distal member 130 has a second curved support surface 132 adapted to support the inferior

5

surface of a distal phalanx of the digit **170** and a curved distal end **134** adapted to apply a compressive force in a proximal direction to a distal end of the distal phalanx **172**.

In some embodiments, the distal member **130** has a hemispherical distal surface which is sized and shaped to receive the most distal end of a digit (toe or finger). In some embodiments, the superior member has cantilever arms **153**, each having a locking tab **154** adapted to mate with the respective slot **116** of the clamping member **110**.

An superior member **150** is configured to be attached to the first clamping member **110** and the distal member **130**. The superior member **150** has a curved surface **152** adapted to apply a force against a superior surface of the digit **170**. When the joint is flexed, the superior member **150** assists in correcting that flex. In some embodiments, the superior member **150** has spring-like material properties, a circular profile, and tabs **154**, which interlock with slots **116** in both the clamping member **110** and distal member **130**. Some embodiments include a plurality of locking tabs **154** or a plurality of slots **116** inferiorly, to allow incremental increase of compression. Each respective slot **116** is configured to receive the at least one tab **154** with the superior member **150** at a respectively different location relative to the proximal member **110** & distal member **130**, for applying a respectively different compressive force in the inferior direction. For example, in the embodiment of FIG. 1, clamping member **110** has two slots **116**, and superior member **150** has tab **154**.

The superior member has means for locking the superior member to the first clamping member and the distal member. In some embodiments, the superior member **150** has one of the group consisting of a slot **116** and a locking tab **154**, either of which provides a locking means. At least one of the first clamping member **110** and the distal member **130** has the other of the group consisting of a slot **116** and a locking tab **154** for engaging the slot or locking tab of the superior member. For example, in the embodiment of FIG. 1, clamping member **110** and distal member **130** each have a slot **116**, and superior member **150** has locking tab **154**. In an alternative embodiment, the superior member **150** has slots, and the clamping member **110** and distal member **130** each have a locking tab for mating with the slots of the superior member **150**. In another embodiment, the superior member has a slot at one end and tab at the other end; one of the clamping member **110** and the distal member **130** has a tab and the other has a slot, for mating with the respective slot and tab of the superior member **150**.

In some embodiments, the clamping member **110**, distal member **130** and superior member **150** are made of padded stainless or titanium alloy.

In some embodiments, one of the first clamping member **110** and the distal member **130** includes at least one locking tab **136**, and the other of the first clamping member **110** and the distal member **130** includes a plurality of slots **118**, **119**. Each respective slot **118**, **119** is configured to receive the at least one locking tab **136** with the distal member **130** at a respectively different location relative to the proximal member **110**, for applying a respectively different compressive force in the proximal direction. For example, in the embodiment of FIG. 1, clamping member **110** has two slots **118** and **119**, and distal member **130** has locking tab **136**. In some embodiments, the locking tab **136** has ramped surface for easy insertion, and for retaining the distal member **130** in position relative to the clamping member **110**, absent an affirmative user action to release the tab **136** from the slot **118** or **119**.

In some embodiments, the slots **116** are substantially longer than the width of tabs **154**, so that the superior member

6

150 can move along the longitudinal (proximal-distal) axis. This allows the selection of slot **118** or **119** to determine the engagement depth of the distal member **130** relative to the clamping member **110**, for control of the compression force against the distal end **172** of the digit **170**.

An exemplary method of using the device **100** is as follows:

1. The user secures the device **100** to the proximal side **171** of the joint, using the adjustable clamping collar **112** on the clamping member **110**.

2. The user assembles the distal member **130** to the clamping member **110** by engaging the tabs **154** of the cantilever arms **153** into the slots **116** of the clamping member **110**.

a. The engagement depth of the tabs **136** determines the amount of axial compression. Various engagement depth options are provided with multiple slots. The embodiment of FIG. 1 has two slots **118**, **119**, providing two engagement depth options. Other embodiments include other numbers of slots for this purpose (e.g., one, three, four or the like).

3. The user assembles the superior member **150** to the clamping member **110** and distal member **130** by compressing the tabs **154** of the superior member **150** inward and aligning the tabs **154** with the mating slots **116** of the clamping member **110** and distal member **130**.

a. The amount of superior compression is determined by the mating features selected (overlapping in the superior I inferior axis by selection of one of the slots **116**), the degree of semi-circularity (i.e., the angle of the sector of a cylinder that the superior member **150** subtends), as well as the material properties of the superior member **150**.

FIG. 4 shows another embodiment of a fixation device **200**. A first clamping member **210** has an adjustable clamping collar (not shown) at its proximal end and a first curved support portion **214** attached to the adjustable clamping collar. The device **200** of FIG. 4 can include any type of clamp **112** described above with respect to the device **100** of FIGS. 1-3, and solely for brevity, descriptions thereof are not repeated. The first clamping member **210** is adapted to receive a digit (not shown). The first curved support portion **214** is adapted to support the inferior surface of a proximal phalanx of the digit. A distal member **230** is adjustably attachable to the first clamping member **210**. The distal member **230** has a second curved support surface **232** adapted to support an inferior surface of a distal phalanx of the digit and a curved distal end **234** adapted to apply a compressive force in a proximal direction to a distal end of the distal phalanx. A superior member **250** is configured to be attached to the first clamping member **210** and the distal member **230**. The superior member **250** has a curved surface **252** adapted to apply a force against a superior surface of the digit.

The device **200** of FIG. 4 differs from the embodiment of FIGS. 1-3 in that it has a different means for locking the superior member to the first clamping member and the distal member. Device **200** has a fully adjustable locking means including at least one suture, strap or band **220** on each side (medial and lateral) of the device **200**. The at least one suture, strap or band **220** is formed of a strong, flexible material, such as nitinol or ultra-high molecular weight polyethylene (UHMWPE) suture material, or nylon. The suture, strap or band **220** is woven through the slots **216**, **217** in the clamping member **210** and distal member, and attached to the tabs **254** of the superior member **250**. The tabs **254** are inserted through one of the slots **216**, selected to control the force applied by superior member **250**.

This embodiment of the device **250** can be placed on the patient while fully assembled and then the suture, strap or band **220** tightened until the desired compression is reached.

The mechanism provides a locking feature such that compression is not lost through repetitious motion.

In some embodiments, the means for locking also includes a release, or unloading, method in the event that the desired compression decreases with time.

Although FIG. 4 shows a suture, strap or band 220, in other embodiments other mechanisms are substituted, such as, but not limited to:

- a. Cable tie configurations
- b. Enhanced hook and loop fastener for increased holding strength
- c. Strap/buckle mating device
- d. Super-elastic ribbon/Shape set to distances that provides compression, stretched to fit over surgical site and allowed to return to its natural state providing the desired compression.
- e. UHMWPE Suture with locking technology integrated in mating features

FIG. 5 shows an embodiment of a fixation device 300, comprising a proximal clamping member 310 and a distal clamping member 311. Each of the proximal and distal clamping members 310, 311 has an adjustable clamping collar 112 adapted to receive a digit 170 therethrough. The device 300 of FIG. 5 can include any type of clamp 112 described above with respect to the device 100 of FIGS. 1-3, and solely for brevity, descriptions thereof are not repeated.

The device 300 has first and second coaxial helical members 322 and 324 opposing each other. For example, in FIG. 5, from left to right, helical member 322 is wound in a clockwise direction around a longitudinal axis of the device 300, and helical member 324 is wound in a counter-clockwise direction around the longitudinal axis. Each of the helical members 322, 324 has a respective proximal end fixedly attached to the proximal clamping member 310 and a respective distal end fixedly attached to the distal clamping member 311. In some embodiments, the helical members 322, 324 are joined to the clamping members 310, 311 by be laser-welded or other suitable technique. Each of the first and second coaxial helical members 322, 324 is in the form of helical band having an inner support surface arranged to be wrapped around the digit 170.

The helical members 322, 324 have spring-like material properties. Flexibility at the joint can be controlled by the stiffness in the material selection for the helical members. In some embodiments, the helical members 322, 324 comprise spring steel or nitinol.

In use, the clamping members 310, 311 are positioned on opposing ends of the joint-line at the surgical/treatment site.

1. The user positions one clamp proximally with respect to the joint line. The user secures the proximal clamp 312 of member 310 to fix the location of device 300.

2. The user extends the free clamp 312 axially in the distal direction, stretching the helical members 322, 324 beyond their relaxed lengths.

3. The user secures the distal clamp 312 of member 311 in the extended position.

Once installed, the helical members 322, 324 react similar to an extension spring as they are strained in extension between two fixed members 310, 311. This results in active compression across the joint acting concurrently with the radial compression created by the clamping action. Device 300 allows some flexion, but, selection of the diameter of the helical members 322, 324 allows the designer to limit the amount of flexion the device 300 affords.

FIGS. 6-11 show an embodiment of a fixation device 400, comprising a proximal clamping member 410 and a distal clamping member 411. Each of the proximal and distal clamping members 410, 411 has an adjustable clamping col-

lar 112 (not shown in FIGS. 6-11) adapted to receive a digit therethrough. The device 400 of FIGS. 6-11 can include any type of clamp 112 described above with respect to the device 100 of FIGS. 1-3, and solely for brevity, descriptions thereof are not repeated.

Device 400 has a plurality of longitudinal spacers 420. Each longitudinal spacer 420 has a proximal end attached to the proximal clamping member 410 and a distal end attached to the distal clamping member 411. Each longitudinal spacer 420 has at least one threaded end, and one of the proximal and distal clamping members 410, 411 has a respective thread configured to receive the threaded end for adjusting a separation between the proximal and distal clamping members. In some embodiments, the clamping members have are counter-sunk to receive nuts 422 for receiving the threads of the spacers 420 (See FIGS. 9 and 10). In some embodiments, spacers 420 are threaded throughout their lengths. In other embodiments, the spacers 420 are threaded at each end, and have a smooth surface in between, configured to receive a tightening instrument (e.g., a wrench) to adjust a distance between the proximal and distal clamping members 410, 411.

Device 400 has a plurality of spring members 430. Each spring member 430 has a proximal end attached to the proximal clamping member 410 and a distal end attached to the distal clamping member 411. For example, as shown in FIG. 9, each end of each spring member 430 fits in a respective slot 412 of clamping members 410 and 411. Each spring member 430 is located adjacent to and radially inward from a respective longitudinal spacer 420. Each longitudinal spacer 420 constrains its respective spring member 430 to bow radially inwards.

In the embodiment of FIGS. 6-11, the plurality of longitudinal spacers 420 includes four longitudinal spacers, and the plurality of spring members 430 include four spring members arranged approximately evenly around a circumference of the proximal clamping member and distal clamping member. Other embodiments include different numbers of spacers 420 and spring members 430 (e.g., 2 or 6).

The device 400 achieves radial compression. The adjustable clamps create a site of fixation on either side of the joint-line. Rotating the spacers 420, with their threaded ends, creates linear extension or retraction of the distance between the clamping members 410, 411.

When the spacers 420 are rotated to reduce the distance between the clamping member 410, 411, the spring members 430 bow and flex inwards as the clamping members 410, 411 translate towards each other, creating radial stability. Device 400 achieves simultaneous radial stability and axial compression at the joint-line.

FIG. 11 shows the device 400 with a detachable drill guide 500 detachably connected to the distal clamping member 411. The detachable drill guide 500 has a guide portion 510 adapted to guide a drill along a proximal-distal axis should an intramedullary device be appropriate. The guide portion 510 has a tapered lead in guide with an opening 512, through which the drill is inserted.

The drill guide 500 comprises a support structure including at least a pair of radial arms 515, 517 and a longitudinal arm 516 for positioning the guide portion 510 a variable distance away from the distal clamping member 411. The radial arms 515, 517 and longitudinal arm 516 are extendible for varying a radial offset and a longitudinal displacement of the guide portion 510 relative to the distal clamping member 411.

Some embodiments provide fine-tuning and adjustable height and length to ensure that the guide is in the desired location in both the longitudinal and superior/inferior directions. Once the desired location is determined, the adjustable

arms lock into place. This achieves accurate and consistent placement of temporary fixation devices or pre-drills. Various mechanisms can be used to provide adjustability. For example, in some embodiments, as shown in FIG. 11A, the drill guide **510** and cylindrical body **520** are an assembly, wherein the cylindrical body **520** replaces the post **515** of FIG. 11. The post **521** has detents **522** at predetermined offsets from each other. The drill guide **510** has at least one spring plunger **523** threaded into the cylindrical body **520** perpendicular to the tapered guide **510**. The spring plungers are biased to engage the post detents, retaining the drill guide **510** in position & will disengage upon sufficient force supplied in the direction of the post axis to allow positional adjustments of the drill guide. In another embodiment, as shown in FIG. 11B, the threaded post **531** is attached to a rod **530** & drill guide **510** as an assembly. The longitudinal post **516** is attached to a threaded nut **532** in which the nut is constrained in translation coaxially and perpendicular to the threaded axis. As the threaded nut **532** is turned, the assembly comprising the threaded post **531**, rod **530** & drill guide **510** will move along the threaded body's axis per the threaded pitch. In other embodiments (not shown), the threaded post **531** mates with a worm gear attached to the post **516**. As the worm gear is turned the assembly comprising the threaded post **531**, rod **530** & drill guide **510** will move along the threaded body's axis per the threaded pitch.

The drill guide **500** has an attachment mechanism **520** which allows it to be secured to one of the clamping members **411**. In some embodiments, the attachment mechanism is a partial collar **520** which matches a portion of the distal clamping member **411**. In other embodiments (not shown), the attachment mechanism is a complete ring, matching the shape of clamping member **411**.

Although the drill guide is only shown in FIG. 11, the drill guide can be used with any of the devices **100**, **200**, or **300** described above.

The material of drill guide **500** can be comprised of either radiopaque or radiolucent materials. A radiolucent material (e.g., hard plastic or glass filled polymer) may be desired if the assembly is to be imaged by fluoroscopy in situ, and the physician does not want the drill guide to appear in the image. A physician may desire a radiopaque material if he/she wishes to establish the position of the drill guide **500** with respect to the bone under fluoroscopy, for example.

FIGS. 12-15 show an embodiment of a fixation device **600** comprising a tube **610** comprising a contractible tubular woven mesh configured to contract radially under longitudinal tension. Such contractible tubular woven meshes are commonly referred to as "Chinese finger traps," and are described, for example, in U.S. Pat. Nos. 2,783,758, 3,872,861 and 5,649,541, which are incorporated by reference herein.

The contractible tubular woven mesh **610** has at least one helical yarn or fiber **630** fastened at or near a first end **611** of the tube **610** and woven helically through the mesh and extending from a second end **612** of the tube **610** opposite the first end **611** of the tube, such that the yarn **630** is capable of applying radial compression to the tube when placed under tension. The helical yarn or fiber **630** is a separate yarn or fiber from those used to form the contractible tubular woven mesh **610**. In some embodiments, the helix of the yarn or fiber **630** winds around the circumference of the tube **610** with a different period than the fibers which constitute the mesh of tube **610**. In some embodiments, the helical yarn or fiber **630** comprises a different material from the material of the tube **610**. The helical yarn or fiber provides a drawstring

In some embodiments, the at least one helical yarn or fiber **630** includes two opposing yarns or fibers **630** extending in

opposite directions around a circumference of the tube **610**. That is, one is configured as a right hand helix and the other is a left hand helix, so that viewed in a direction of the longitudinal axis of the tube **610**, one helix winds clockwise around the tube, and the other helix winds counter-clockwise around the tube. In some embodiments, the yarn or fiber **630** includes a circular winding (in a plane perpendicular to the longitudinal axis of the tube **610**) at each end of the tube **610**, so that pulling the string causes both radial compression and cinching of the ends of the tube **610**. The helix crosses in the middle of the fixation device **600** such that when cinched, the contraction of the helical yarn or fiber **630** causes a bent joint to straighten through the application of a compressive force along the helix.

The device **600** is slipped over the digit to be treated, and the at least one helical yarn or fiber **630** is (are) pulled and tied or fastened. The at least one helical yarn or fiber **630** act as a drawstring, cinching the tube **610** and placing the tube in radial compression. In some embodiments, the device **600** is used to straighten the digit (e.g., toe) for percutaneous drilling into the end of the toe. The mesh will compress the toe while holding it rigid in line for drilling. This device **600** can also be used for minor adjustment until the soft tissue releases.

In some embodiments, the user attaches a weight to the yarns or fibers **630** to maintain compression during a surgical procedure. In other embodiments, the device **600** is used to provide stability post-surgery for a length of time by pulling, cinching and tying off the helical yarns or fibers **630**. The device **600** can provide compression and help correct deformity.

In some embodiments, the device **600** is used alone to provide compression and support. In some embodiments, additional support and rigidity is provided by inclusion of optional sleeves **620**. In some embodiments, a plurality of sleeves **620** are arranged around an outer surface of the tube **610**. The sleeves **620** are substantially smaller in diameter than the tube **610**. Any number of sleeves **620** may be included. In some embodiments, four, six or eight sleeves **620** are uniformly distributed about the circumference of the tube **610**. In some embodiments, the sleeves **620** comprise the same material as the mesh of tube **610**. In other embodiments, the sleeves comprise a different material from tube **610**.

Each of the plurality of sleeves **620** has a respective first end fixed at or proximate to a first end **611** of the tube **610** and a respective second end fixed at or proximate to a second end **612** of the tube **610** opposite the first end **611**. Each sleeve **620** has a portion that is freely movable relative to the tube **610**, the portion being between the first end and second end of each sleeve. In some embodiments, the sleeves are only fixed (e.g., by sewing) at their ends to the respective ends **611**, **612** of the tube **610**, and the sleeves are free to move relative to the tube at all intermediate locations along the lengths of the sleeves. In other embodiments, the sleeves **620** are fixed at both ends and at one or more intermediate points along their length to the outer surface of the tube **610**. In other embodiments, the sleeves **620** are sewn at or near one end of the tube **620**, and the other end of each sleeve **620** is free to move relative to the tube **610**.

In some embodiments, the user can optionally insert at least one removably insertable rib **622** in at least a respective one of the plurality of sleeves **620**. In some embodiments, the ribs are inserted after pulling the helical yarns or fibers **630** to cinch the tube **610**. The at least one rib **622** is formed of a material that is more rigid than a material of the tubular woven mesh. The rib can comprise any of a variety of materials, such as wood, plastic or a more rigid material.

11

FIG. 15 shows the device 600 after the user inserts six ribs 622 in the respective sleeves 620. The physician can determine on an individual basis how many ribs to insert, if any, and where to put the ribs to achieve desired rigidity in a directional manner. Thus, the physician can select placements of the ribs to increase rigidity in the lateral-medial direction, or in the superior-ventral direction.

FIGS. 12-15 show an embodiment of device 600 having both the helical yarns or fibers 630 and the sleeves 620. In other embodiments, the device includes a tube 610 with the sleeves 620, but without the helical yarns or fibers 630. In other embodiments, as shown in FIGS. 15A-15C, the device 650 includes a tube 610 with the helical yarns or fibers 630, but without the sleeves 620. When cinched, the helical yarns or fibers 630 causes a bent joint of digit 170 to straighten through the application of a compressive force along the helix.

Although FIGS. 12-15C show the device 600 used alone, the device 600 can be used in combination with any of the devices shown in FIGS. 1-11. In particular, in some embodiments, the device 300 (FIG. 5) or 400 (FIGS. 6-11) can be applied over the device 600. The physician applies device 600 and cinches the helical yarns or fibers 630, and optionally inserts one or more ribs 622 in sleeves 620. Then the physician places the device 300 or 400 over the digit and tightens the clamps 312 or 112 at each end of the device 300 or 400. The physician attaches the drill guide 500 and performs the drilling (e.g., for K-wire insertion). This is just one example, and the device 600 can be used with other external fixation devices to provide compression and support during surgical procedures.

FIGS. 16-19 show an embodiment of a bone implant 700 suitable for correcting a deformity such as a hammertoe. This device 700 addresses the common secondary procedure stabilize the metatarsophalangeal (MTP) joint by releasing the joint capsule and employing a temporary fixation wire. The bone implant 700 comprises a helical threaded member 710 having first and second ends 704, 706 and a longitudinal central opening 708 extending from the first end 704 to the second end 706. The longitudinal central opening has a longitudinal axis 702.

At least one blade 720 integrally attached to the first end 704 of the helical threaded member 710. The blade 720 extends in a radial direction away from the longitudinal axis 702. The blade 720 has an outer edge with a plurality of teeth thereon 722. The blade 720 has an outer edge with a plurality of teeth thereon 722. In some embodiments, as shown in FIGS. 16-19, the implant 700 has two blades evenly spaced and symmetrically arranged to extend in opposite radial directions away from the longitudinal axis 702. A central tube 730 with a central cannula 732 runs along the central axis for a portion of the length of the helical threaded member.

In some embodiments, as shown in FIGS. 16-19, the helical threaded member 710 has a cork-screw shape. The central longitudinal opening (referred to herein as a cannula) of the helical threaded member 710 is open to the exterior of the device. The central opening 708 is continuous with the cannula 732 of the central tube 730 and the cannula 724 which extends to the end of blades 720. This configuration is analogous to a cannula diameter greater than the minor diameter of a screw. The cork screw configuration allows implantation over a k-wire, which is used to address metatarsophalangeal (MTP) joint soft-tissue contracture. The cork-screw configuration of helical threaded member 710 allows both axial compression (FIG. 17) and extension (FIG. 18) and perpendicular bending flexion (FIG. 19), similar to the range of motion of a coiled spring. This provides additional flexibility in the joint

12

as well as enhanced bone integration within the threads of the helical threaded member 710. The degree of flexibility is a function of material properties and geometry and can be controlled and optimized.

In some embodiments, implant 700 comprises a material having super-elastic material properties, such as nitinol. In other embodiments, the material is selected to include shape memory properties. Shape memory alloys, such as Nickel Titanium (nitinol), undergo a phase transformation in their crystal structure when cooled from the stronger, high temperature form (Austenite) to the weaker, low temperature form (Martensite). When heated after deformation, the shape memory material recovers its original shape. For example, an implant 700 formed of a material with shape memory is set in the expanded state (FIG. 18), and implanted. Then the device 700 compresses when introduced into the body due to temperature increase (FIG. 17). This ensures compression at the joint while maintaining some flexibility. Also, nitinol exhibits superelasticity if deformed in an environment above their transformation temperatures and will change phase from austenite to stress-induced martensite, allowing it to be strained from ~2-6% with nearly constant stress & return from martensite to austenite during unloading.

In the configuration as shown, the cantilevered blades 720 deflect inwards when radial force is applied, allowing compatibility with an undersized preparation hole. When inserted in the bone, the cantilever blades 720 flex outward increasing fixation in the bone. The outward spring force of the blades 720 is a function of the material properties and geometry, and can be controlled and optimized.

FIG. 20 shows an embodiment of a device 800 which is similar to the device 700 of FIGS. 16-19, except that a single blade 820 with teeth 822 is provided. The bone implant 800 comprises a helical threaded member 810 having first and second ends 804, 806 and a longitudinal central opening 808 extending from the first end 804 to the second end 806. Device 800 is partially cannulated, providing greater flexibility along the helical threaded member 810, along the axis 802 from the first end 804 to the second end 806. Compared to the device 700, the single blade configuration of blade 820 provides greater rigidity when inserted in the bone. In some embodiments, the device 800 comprises a superelastic, shape memory alloy, such as nitinol, providing the expansion/contraction properties of the device 700, but with greater rigidity.

FIG. 21 shows an embodiment of a partially cannulated device 900 which is similar to the device 800 of FIG. 20, except that four perpendicular blades 920 with teeth 922 are provided in a continuous, cross-blade configuration. The bone implant 900 comprises a helical threaded member 910 having first and second ends 904, 906 and a longitudinal central opening 908 extending from the first end 904 to the second end 906. Compared to the devices 700 and 800, the cross-blade configuration of blades 920 provides greater rigidity when inserted in the bone. The cross-blade configuration can provide a greater degree of fixation. The cross-blade configuration allows implant pre-drill (circular) preparation instead of broaching. Using an undersized pre-drill step, the crossed blades 920 achieve fixation by circumferential interference with the surrounding bone. In some embodiments, the device 900 comprises a superelastic shape memory alloy, such as nitinol, providing the expansion/contraction properties of the device 700 described above but with greater rigidity & fixation

FIG. 22 shows an embodiment of a fully cannulated device 1000 which is similar to the device 700 of FIGS. 16-20, except that four perpendicular blades 1020 are provided in a cross-blade configuration, evenly spaced around the longitu-

13

dinal axis. The central opening **1008** is continuous with the cannula (not shown in FIG. **22**) of the central tube **1030** and the cannula **1024** which extends to the end of blades **1020**. A K-wire or the like can be placed through the central opening **1008** of helical threaded member **1010**, along the axis **1002** from the first end **1004** to the second end **1006**. Compared to the device **700**, the four blade configuration of blades **1020** can provide a greater degree of fixation. The cross-blade configuration allows implant pre-drill (circular) preparation instead of broaching. Using an undersized pre-drill step, the crossed blades **1020** achieve fixation by circumferential interference with the surrounding bone. In the configuration of FIG. **22**, the four cantilevered blades **1020** deflect inwards when radial force is applied, allowing compatibility with an undersized preparation hole. When inserted in the bone, the cantilever blades **1020** flex outward increasing fixation in the bone. The outward spring force of the blades **1020** is a function of the material properties and geometry, and can be controlled and optimized. In some embodiments, the device **1000** comprises a superelastic, shape memory alloy, such as nitinol.

FIGS. **23** and **24** show an embodiment of a fully cannulated implant **1100** which is similar to the device **1000** of FIG. **22**, except that the helical threaded member **1110** of implant **1100** has a minor diameter larger than a diameter of the longitudinal central opening **1124**, so that the helical threaded member **1110** has a central tube **1140** with a continuous inner surface **1142** around the longitudinal central opening (cannula) **1124**. In implant **1100**, four perpendicular blades **1120** with teeth **1122** are provided in a cross-blade configuration, evenly spaced around the longitudinal axis **1102**. In other embodiments, only two cantilever blades (similar to blades **720** in FIG. **16**) are provided, but the rest of the implant **1100** is otherwise the same. In some embodiments, the device **1000** comprises a superelastic, shape memory alloy, such as nitinol.

A K-wire or the like can be placed through the central opening **1124** of helical threaded member **1110**, along the axis **1102** from the first end **1104** to the second end **1106**. Compared to the device **700**, the four blade configuration of blades **1120** can provide a greater degree of fixation. The cross-blade configuration allows implant pre-drill (circular) preparation instead of broaching. Using an undersized pre-drill step, the crossed blades **1120** achieve fixation by circumferential interference with the surrounding bone.

FIGS. **25-29** show a method for installing the implant **1100**. The same sequence of steps is performed for any of the fully cannulated implants, such as implant **700** (FIG. **16**), and implant **1000** (FIG. **22**). Note that in the views of FIGS. **25-27**, the proximal direction is left and the distal direction is right, but in the views of FIGS. **28** and **29**, the proximal direction is right and the distal direction is left.

In FIG. **25**, the proximal bone (phalanx) **2503** is pre-drilled to receive the K-wire **1126**, and the physician broaches the middle phalanx **2502**.

Then, the physician drills distally through middle phalanx **2502** and through the tip of the toe **2501** with the K-wire **1126**, as shown in FIG. **26**.

Once the K-wire is exposed, a drill **2510** (shown in FIG. **27**) is attached to the distal end of the K-wire **1126**. The K-wire **1126** is backed out towards the distal end of the bone **2501**, until the proximal tip of the K-wire **1126** is sub-flush with the joint line (i.e., withdrawn past the proximal end of middle phalanx **2502**). In some embodiments, the K-wire is drawn past the end of the middle phalanx **2502** by a distance greater than a length of the blades **1120**.)

The helical threaded portion **1110** of the implant **1100** is then advanced into the proximal phalanx **2503** until the

14

implant **1100** is fully seated. Once the implant **1100** is fully seated, the physician closes the joint, forcing the blades **1120** into the previously broached canal as shown in FIG. **28**.

With a correctly aligned joint (optionally using one of the external fixation devices shown in FIGS. **1-15**), the physician advances the K-wire **1126** in the proximal direction, through the cannulated implant **1100** into the MP joint. The physician caps the K-wire **1126** with a Jurgan ball **1128**, completing the installation.

FIGS. **30-34** show a bone implant **1200** comprising a central shaft **1210** having first and second ends and a longitudinal axis. A first set of blades **1220** are integrally attached to the first end of the central shaft **1210**. The first set of blades **1220** extends in a radial direction away from the central shaft **1210**. Each of the first set of blades **1220** has an outer edge with a plurality of teeth **1222** thereon.

A second set of blades **1250** with teeth **1252** are integrally attached to the second end of the central shaft **1210**. The second set of blades **1250** extend in the radial direction away from the central shaft **1210**. Each of the second set of blades **1250** has an outer edge with a plurality of teeth **1222** thereon. The second set of blades are rotationally offset from the first set of blades.

In some embodiments, each one of the second set of blades **1250** is rotationally spaced midway between an adjacent pair of the first set of blades **1210**. For example, in the implant of FIGS. **30-34**, there are four first blades **1220** and four second blades **1250**. The angular spacing between each second blade **1250** and the adjacent first blades **1210** on either side is 45 degrees. FIGS. **31** and **32** show the angular offsets between the two sets of blades **1220**, **1250**.

In some embodiments, the bone implant **1200** has a cannula **1224** extending along the longitudinal axis **1202** from a first end of the bone implant to a second end of the bone implant. In other embodiments, the implant is solid, with no cannula. In some embodiments, the device **1000** comprises a superelastic, shape memory alloy, such as nitinol.

In some embodiments, an instrument is provided that inserts a broach in the bone on one side of the joint in a first orientation, and then is rotated ± 45 degrees to broach the bone on the other side of the joint in a second orientation rotationally offset from the first orientation. The instrument has a shape to match the cross-blade configuration **1220** of the implant **1200**. In other embodiments, a K-wire channel is pre-drilled into the bone prior to inserting the implant, and no broach is required. In either case, the physician uses a safety tool to handle the implant **1200**. The safety tool has a gripping handle and a head shaped to receive either the blades **1220** or the blades **1250**, so the physician is not harmed by the blades **1220**, **1250**.

The inventors have determined that one of the sources of problems in hammertoe implants is implant loosening after insertion. The rotational offset between blades **1220** and blades **1250** provides a different orientation on the distal end and the proximal end to help prevent against the blades from loosening.

FIGS. **33-34** show the method of insertion. First, the bones **2501-2503** are pre-drilled as shown and described above with reference to FIGS. **25-27**, and the physician inserts the K-wire **1126** across the joint. The alignment may be checked by fluoroscopy to confirm where to insert the implant. The K-wire **1126** is backed out beyond the proximal end of the middle phalanx **2502**.

As shown in FIG. **33**, the physician inserts the blades **1220** of implant **1200** in the proximal phalanx **2503**, where the K-wire pre-drilled hole is visible. The physician can use the above-mentioned safety tool for this purpose.

15

Then as shown in FIG. 34, the physician takes the PIP joint and places the broached or pre-drilled side of the middle phalanx 2502 over the blades 1250 and presses the middle phalanx into place, with the implant now embedded in both the middle phalanx 2502 and the proximal phalanx 2503.

If the implant 1200 is cannulated, then the K-wire 1126 is advanced through the implant in the same manner described above with reference to FIG. 29, and a Jurgan ball 1128 is attached.

Although the subject matter has been described in terms of exemplary embodiments, it is not limited thereto. Rather, the appended claims should be construed broadly, to include other variants and embodiments, which may be made by those skilled in the art.

What is claimed is:

1. A bone implant comprising:

a helical threaded member having first and second ends and a longitudinal central opening extending from the first end to the second end, the longitudinal central opening having a longitudinal axis, wherein the helical threaded member has a cork-screw shape without a central cylindrical wall; and

at least one blade integrally attached to the first end of the helical threaded member, the blade extending in a radial direction away from the longitudinal axis, the blade having an outer edge with a plurality of teeth thereon.

2. The bone implant of claim 1, wherein the at least one blade includes two or four blades evenly spaced around the longitudinal axis.

3. The bone implant of claim 1, wherein the longitudinal central opening extends to an end of the at least one blade opposite the helical threaded member.

4. The bone implant of claim 1, wherein the bone implant comprises a shape memory alloy.

5. The bone implant of claim 1, wherein the bone implant comprises a superelastic alloy.

6. The bone implant of claim 1, wherein the bone implant comprises nitinol.

7. The bone implant of claim 1, wherein the longitudinal central opening has a diameter that corresponds to a minor diameter of a helical thread of the helical threaded member.

8. The bone implant of claim 1, wherein the at least one blade includes four blades evenly spaced around the longitudinal axis.

9. The bone implant of claim 8, wherein the four blades are cantilevered and configured for flexing inwards or outwards.

10. A method of using the bone implant of claim 1, wherein the bone implant comprises a shape memory alloy having an original shape, the method comprising:

implanting the bone implant while the bone implant is in an expanded state; and

allowing a temperature of the bone implant to increase after implantation, so as to cause the bone implant to return to the original shape of the bone implant and cause compression of a joint.

11. A method of using the bone implant of claim 1, wherein the bone implant comprises a superelastic alloy having a transformation temperature, wherein the bone implant has been expanded above the transformation temperature so as to cause a phase change from austenite to stress-induced martensite, the method comprising:

implanting the bone implant; and

allowing the bone implant to return from martensite to austenite to cause compression at a joint.

16

12. A bone implant comprising:

a central shaft having first and second ends and a longitudinal axis; and

a first set of blades integrally attached to the first end of the central shaft, the first set of blades extending in a radial direction away from the central shaft, each of the first set of blades having an outer edge with a plurality of teeth thereon; and

a second set of blades integrally attached to the central shaft, the second set of blades extending in the radial direction away from the central shaft, each of the second set of blades having an outer edge with a plurality of teeth thereon, the second set of blades rotationally offset from the first set of blades, the first and second set of blades cantilevered for flexing inward or outward radially.

13. The bone implant of claim 12, wherein the helical threaded member has a minor diameter larger than a diameter of the longitudinal central opening, so that the helical threaded member has a continuous inner surface around the longitudinal central opening.

14. The bone implant of claim 12, wherein each one of the second set of blades is rotationally spaced midway between respective ones of the first set of blades.

15. The bone implant of claim 12, wherein the bone implant has a cannula extending along the longitudinal axis from a first end of the bone implant to a second end of the bone implant.

16. The bone implant of claim 12, wherein the bone implant comprises a shape memory alloy.

17. The bone implant of claim 12, wherein the bone implant comprises a superelastic alloy.

18. The bone implant of claim 12, wherein the bone implant comprises nitinol.

19. A bone implant comprising:

a helical threaded member having first and second ends and a longitudinal central opening extending from the first end to the second end, the longitudinal central opening having a longitudinal axis, wherein the helical threaded member has a cork-screw shape, and the longitudinal central opening penetrates in a radial direction to an exterior of the device continuously along a length thereof; and

at least two cantilevered blades integrally attached to the first end of the helical threaded member, the cantilevered blades extending in a radial direction away from the longitudinal axis for flexing inward or outward radially, each cantilevered blade having an outer edge with a plurality of teeth thereon.

20. The bone implant of claim 19, wherein the at least two cantilevered blades include four cantilevered blades evenly spaced around the longitudinal central opening.

21. The bone implant of claim 20, wherein the bone implant comprises nitinol.

22. The bone implant of claim 19, wherein the cork-screw shape of the helical threaded member is configured without a central cylindrical wall and adapted for axial compression and extension, and perpendicular bending flexion.

* * * * *